

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.1 Generate hypotheses on the basis of credible, accurate, and relevant sources of scientific information.

Taxonomy Level: 6.1-B Create Conceptual Knowledge

Key Concepts: hypotheses, sources of scientific information

Previous/Future knowledge: Students were introduced to a hypothesis in 5th grade (5-1.1) as students identified questions suitable for generating a hypothesis. A more in-depth understanding of the processes and importance of using credible, accurate, and relevant sources of scientific information is expected for Physical Science. Generating hypotheses is the basis for conducting scientific investigations and is therefore vital to the understanding of the scientific inquiry process in Physical Science and all high school science courses.

It is essential for students to

- Know that a hypothesis is a reasonable explanation of an observation or experimental result or a possible answer to a scientific question that can be tested. The hypothesis may or may not be supported by the experimental results. It is often stated in terms of an independent and a dependent variable—or a “cause-effect relationship.” Examples of hypotheses might include:
 - If an object has greater surface area, then the rate at which it falls through the air decreases.
 - As the volume of an object increases, the rate at which it fall through air decreases.
 - With a constant force, an object with a smaller mass will accelerate more than an object with a larger mass.
 - If I make a paper airplane with larger wings, then the airplane will glide farther, because the additional surface area of the wing will produce more lift.
- Know that the results of an experiment cannot prove that a hypothesis is correct. Rather, the results support or do not support the hypothesis. Valuable information is gained even when the hypothesis is not supported by the results. For example, it would be an important discovery to find that the wing size is not related to how far an airplane glides. When hypotheses are tested over and over again and not contradicted, they may become known as laws or principles.
- Use *credible* (trustworthy), *accurate* (correct – based on supported data), and *relevant* (applicable, related to the topic of the investigation) sources of scientific information in preparation for generating a hypothesis. These sources could be previous scientific investigations science journals, textbooks, or other credible sources, such as scientifically reliable internet sites.

Teacher Note:

Some sources of information are not based on credible scientific research and may contain information that is not accurate. Credible science investigations are published in journals that are reviewed by a panel of respected research scientists active in the field of science being studied. Teachers could help students identify credible sources of scientific information that may help them with background information for their hypotheses. Teachers must also caution students to be skeptical of website information and journal articles that are not referenced to credible sources of scientific research.

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It is not essential for students to

- Reference research from outside sources for every hypothesis written, but if scientific information is needed for generating a hypothesis, it must be credible, accurate, and reliable;
- Name specific journals or websites, but the understanding of what makes a source credible and reliable is part of this indicator;
- Understand the concept of the null hypothesis.

Assessment Guidelines:

The objective of this indicator is to *generate* hypotheses on the basis of credible, accurate, and relevant sources of scientific information, therefore, the primary focus of assessment should be for students to formulate a credible hypothesis for an investigation. Students must have an understanding of how the relationship between the independent and dependent variables are related in a hypothesis.

In addition to *generate*, assessments may require that students:

- *Identify* the variables involved in a hypothesis;
- *Use* data to determine whether a hypothesis was supported or not supported by that data;
- *Summarize* the criteria by which scientific information would be used to help generate the hypothesis.

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PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.2 Use appropriate laboratory apparatuses, technology, and techniques safely and accurately when conducting a scientific investigation.

Taxonomy Level: 3.1-C Apply Procedural Knowledge

Key Concepts: laboratory apparatus, laboratory technology, laboratory techniques, scientific investigation

Previous/Future knowledge: Students were introduced to this topic with specific tools identified at each grade level as follows: (K-1.2) magnifiers and eyedroppers; (1-1.2) rulers; (2-1.2) thermometers, rain gauges, balances, measuring cups; (3-1.5) beakers, meter tapes and sticks, forceps/tweezers, tuning forks, graduated cylinders, graduated syringes; (4-1.2) compass, anemometer, mirrors, prism; (5-1.4) timing device and 10x magnifier; (6-1.1) spring scale, beam balance, barometer, sling psychrometer; (7-1.1) microscope; (8-1.6) convex lenses, plane mirrors, color filters, prisms, slinky springs. With more complex scientific investigations, many more tools will be used in Physical Science. Using technology while conducting scientific investigations and specific laboratory techniques will also be an important component of Physical Science developing laboratory skills essential for the study of Biology, Chemistry, and Physics.

It is essential for students to

- Use appropriately and identify the following laboratory apparatuses and materials:

Apparatuses and materials appropriate for chemistry investigations of Physical Science:

| | |
|-------------------------------------|---|
| Balances, triple beam or electronic | Pipettes / droppers |
| Beakers | pH paper / pH meters |
| Burners (Bunsen), flint strikers | Ring stand, ring clamp, and test tube clamp |
| Chemical scoop | Stirring rods |
| Conductivity apparatus (light bulb) | Stoppers – rubber, cork |
| Erlenmeyer flasks | Test tubes, holder, and rack |
| Evaporating dishes | Test tube brushes |
| Filter paper | Thermometers (alcohol, digital) |
| Forceps | Tongs (crucible, beaker) |
| Funnels | Watch glasses |
| Graduated cylinders | Wire gauze with ceramic centers |
| Hot plates | Wood splints |
| Litmus paper | |

Apparatuses and materials appropriate for physics investigations of Physical Science:

| | |
|---|----------------------------|
| Ammeters and voltmeters (or multimeters) | Motion carts (or toy cars) |
| Compasses | Motors, simple electric |
| Diffraction grating | Protractors |
| Dry cells (or other voltage source) | Resistors |
| Electroscopes | Slinky springs |
| Flashlights | Spectroscope |
| Generators (hand-held) | Spring scales |
| Hand lenses (magnifiers) | Switches, knife |
| Lenses (convex and concave) | Timers |
| Light bulb and holders | Tuning forks |
| Magnets | Weights |
| Mirrors, plane rectangular | Wire, insulated copper |
| Measuring tools: Metric rulers, Meter sticks, and meter tapes | |

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- Use the identified laboratory apparatuses in an investigation safely and accurately with
 - Associated technology, such as
 - computers, calculators and other devices, for data collection, graphing, and analyzing data, or
 - probeware and meters to gather data; and
 - Appropriate techniques that are useful for understanding chemistry and physics concepts, such as
 - measuring, heating, filtering, timing, and
 - setting up circuits, electrostatics, or
 - wave behavior.

NOTE TO TEACHER: Other useful materials and apparatuses to support the standards include

Chemicals as needed for planned labs

Computers with access to the Internet

Laser

Microscale supplies where appropriate

Molecular models

Ripple tank

Static electricity materials: plastic and glass rods; wool, fur, and silk fabric; pith balls

Supports, lenses, screen, meter sticks (for simple optical benches)

Tripod lens

Vacuum pump, bell jar, and bell

Van de Graaf generator

Wire cutters

It is not essential for students to

- Cut or bend glass tubing or insert it in rubber stoppers;
- Understand how probeware from a specific manufacturer functions.

Assessment Guidelines:

The objective of this indicator is to use appropriate laboratory apparatuses, technology, and techniques safely and accurately, therefore the primary focus of assessments should be to determine the proper use of the apparatuses, technology, and techniques for scientific investigations. Students must show an understanding of how the apparatuses are used safely and accurately.

In addition to *use*, assessments may require that students:

- Identify an apparatus from a description or illustration;
- Recognize appropriate laboratory apparatuses, technology, and techniques for given procedures;
- Recognize safety guidelines associated with use of laboratory apparatuses, technology, and techniques;
- Exemplify appropriate apparatuses, technology, and techniques needed for a scientific investigation;
- Infer which laboratory apparatuses, technology, and techniques are appropriate for given procedures and that will produce accurate results.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.3 Use scientific instruments to record measurement data in appropriate metric units that reflect the precision and accuracy of each particular instrument.

Taxonomy Level: 3.1-C Apply Procedural Knowledge

Key Concepts:

Reading scientific measuring instruments:

graduated cylinders, balances, spring scales, thermometers, rulers

Measurement data

Metric units

Precision and accuracy

Previous/Future knowledge: In the 1st grade students used rulers “accurately and appropriately” (1-1.2) but only used standard English units of measurement. In the 2nd grade students used thermometers and balances (2-1.2). By the 3rd grade students used meter tapes and graduated cylinders (3-1.5) and by the 6th grade spring scales and beam balances are used (6-1.1). In Physical Science the students will record measurement data in appropriate metric units using the correct number of decimals by estimating the last digit on the measurement scale of the instrument. Significant figures will be addressed in Chemistry (C-1.1) or Physics (P-1.1).

It is essential for students to

- Read scientific instruments such as graduated cylinders, balances, spring scales, thermometers, rulers, meter sticks, ammeters, voltmeters (or multimeters), and stopwatches using the correct number of decimals to record the measurements in appropriate metric units.
- The measurement scale on the instrument should be read with the last digit of the recorded measurement being estimated.
- Record data using appropriate metric units (SI units). They should be able to use prefixes; milli, centi, kilo. (Conversions should be made using dimensional analysis – see PS 1-5)
- Understand that the more decimals in the recorded measurement, the greater the precision of the instrument.
 - An instrument that can be read to the hundredths place is more precise than an instrument that can be read to the tenths place.
 - A 100 mL graduated cylinder that is marked in 1 mL increments can be read exactly to the ones place with the tenths place being estimated in the recorded measurement.
 - A 10 mL graduated cylinder that is marked in 0.1 mL increments can be read exactly to the tenths place with the hundredths place being estimated in the recorded measurement.
 - The 10 mL graduated cylinder, therefore, is more precise than the 100 mL graduated cylinder.
- Understand that the terms *precision* and *accuracy* are widely used in any scientific work where quantitative measurements are made.
 - **Precision** is a measure of the degree to which measurements made in the same way agree with one another.
 - The **accuracy** of a result is the degree to which the experimental value agrees with the true or accepted value.
 - It is possible to have a high degree of precision with poor accuracy. This occurs if the same error is involved in repeated trials of the experiment.

Scientific Inquiry

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It is not essential for students

- to identify the number of significant figures in measurements or
- to understand their use in calculations;
- to understand the difference between systematic and random measurement errors, or
- to define the degree of uncertainty of measurements.

Assessment Guidelines:

The major objective of this indicator is to use scientific instruments to record measurement data in appropriate metric units reflecting the precision and accuracy of each instrument, therefore, the primary focus of assessment should be to apply proper procedures to using instruments and record the data from the instruments accurately. Assessment items will require that students understand precise and accurate measurements and that all measurement data must have appropriate metric units associated with the digits.

In addition to use, assessment may require that students:

- Exemplify precise and accurate measurements;
- Compare precise vs. accurate measurement data;
- Summarize accuracy and precision with specific scientific instruments in making measurements;
- Infer that measurements vary in precision and accuracy;
- Identify the appropriate instrument that meets the measurement need and appropriate precision for a designated experiment.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.4 Design a scientific investigation with appropriate methods of control to test a hypothesis (including independent and dependent variables), and evaluate the designs of sample investigations.

Taxonomy Level: 6.2-C Create Procedural Knowledge

5.2-B Evaluate Conceptual and Procedural Knowledge

Key Concepts:

Scientific investigation: Hypothesis, Independent variable, Dependent variable

Methods of control: Controlled variable, Control group

Previous/Future knowledge: In the 4th grade (4-1.3), students summarized the characteristics of a simple scientific investigation that tests one manipulated variable at a time. In the 5th grade (5-1.3), students planned and conducted controlled scientific investigations, manipulating one variable at a time. In the 6th and 7th grades (6-1.1 and 7-1.1), students conducted controlled scientific investigations, and in the 8th grade (8-1.1), students designed controlled scientific investigations. In the 7th grade (7-1.5), students explained the relationships between independent and dependent variables in controlled scientific investigations. While students identified questions suitable for generating a hypothesis (5-1.1) that could be answered through scientific investigation (7-1.2) and (8-1.4), in Physical Science students will design and evaluate designs of controlled scientific investigations to test a hypothesis with stated independent and dependent variables. In chemistry (C-1.4) and in physics (P-1.4) students will expand the idea of designing and evaluating scientific investigations.

It is essential for students to

- Design a controlled scientific investigation in which one variable at a time is deliberately changed and the effect on another variable is observed while holding all other variables constant.
The steps in designing an investigation include:
 - Stating the purpose in the form of a testable question or problem statement
 - Researching information related to the investigation
 - Stating the hypothesis
 - Describing the experimental process
 - Planning for independent and dependent variables with repeated trials
 - Planning for factors that should be held constant (controlled variables)
 - Setting up the sequence of steps to be followed
 - Listing materials
 - Planning for recording, organizing and analyzing data
 - Planning for a conclusion statement that will support or not support the hypothesis
- Understand that scientific investigations are designed to answer a question about the relationship between two variables in a predicted “cause-effect relationship.”
- Understand that the statement that predicts the relationship between an independent and dependent variable is called a *hypothesis*.
- Understand that the *independent variable* is the variable that the experimenter deliberately changes or manipulates in an investigation.
- Understand that the *dependent variable* is the variable that changes in an investigation in response to changes in the independent variable.

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- Understand that the independent variable is the “cause” and the dependent variable is the “effect” in the “cause-effect” relationship that is predicted.
- Understand that all the other possible variables in the investigation should be held constant so that only one variable (the independent) is tested at a time. The variables which are held constant are called *controlled variables*.
- Understand that the investigator should conduct repeated trials to limit random error in measurements.
- Understand that, when appropriate, a *control group* is set up as a basis of comparison to test whether the effects on the dependent variable came from the independent variable or from some other source.

It is also essential for students to

- Evaluate the design of an experiment by assessing whether the steps of the investigation are presented.
- Evaluate the methods by which the investigation was conducted to determine:
 - Whether independent and dependent variables are appropriate for testing the hypothesis;
 - Whether only one variable is changed at a time by the investigator;
 - Which variables are, or should have been, controlled;
 - Whether data was collected with adequate repeated trials, organized and analyzed properly;
 - Whether the conclusion is logical based on the analysis of collected data.

Teacher Note: Many science laboratory activities simply give students procedures to follow, data to collect and graph, and questions to answer that verify their learning of the concepts. Science learning can be more interesting to students if they are given the opportunity to explore and wonder “why” more often. If students conduct an investigation in which something unexpected or unusual happens and then are asked to predict why it happened, they feel more involved in the learning. Then, if they are asked to *design an experiment* to see if their prediction is correct, they will feel empowered by the activity. These activities are often called “Open Inquiry” or “Guided Inquiry” depending on how much instruction is provided. Teachers should encourage students to be curious and wonder why things happen. Science fair projects can be a perfect opportunity for students to conduct these kinds of activities. Instruction and guidance should be provided to insure that proper investigative procedures are followed.

It is not essential for students to

- Understand the null hypothesis process.
- Perform statistical analysis on the data to evaluate the experimental design.

Assessment Guidelines:

The first objective of the indicator is to *design* a scientific investigation with appropriate methods of control to test a hypothesis; therefore the primary focus of assessment should be for students to demonstrate understanding of the components of a properly designed scientific investigation.

In addition to *design*, students should be able to:

- Classify the types of variables and constants in a controlled investigation;
- Summarize the components of a controlled scientific investigation.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

Another objective of this indicator is to *evaluate* the designs of sample investigations; therefore, the primary focus of assessment should be to critique the components of a controlled scientific investigation by determining whether the investigation has met the criteria for testing a particular hypothesis.–

In addition to *evaluate*, students should be able to:

- *Interpret* the data to *infer* a relationship between the variables predicted by the hypothesis;
- *Interpret* the data to determine if the conclusion is valid;
- *Check* the investigation results to determine if the hypothesis is supported;
- *Relate* the hypothesis to an appropriate scientific investigation;
- *Identify* the components of a scientific investigation.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.5 Organize and interpret the data from a controlled scientific investigation by using mathematics (including formulas and dimensional analysis), graphs, models, and/or technology.

Taxonomy Level: 4.2-B Analyze Conceptual Knowledge
2.1-B Understand Conceptual Knowledge

Key Concepts:

| | |
|-------------------------------------|--|
| Data | Graphs |
| Controlled scientific investigation | Direct and Inverse variations (proportion) |
| Formulas | Models |
| Dimensional analysis | Technology |

Previous/Future knowledge: In the 6th grade, students analyzed and interpreted data to distinguish between an observation and inference (6-1.2). In the 7th grade, students used graphs, tables, and charts to explain the relationship between independent and dependent variables (7-1.5) while they interpreted data to construct explanations and conclusions in the 8th grade (8-1.3). In Physical Science PS-1.1 and PS-1.4, students generate hypotheses and design scientific investigations. This indicator (PS-1.5) expands on these processes by requiring that students organize and interpret data using mathematics with formulas and dimensional analysis, graphs, models, and technology. Indicator PS-1.7 requires that students evaluate results to refute or verify a hypothesis. Significant figures will be addressed in chemistry (C-1.5) and in physics (P-1.5) scientific notation will be addressed.

It is essential for students to

- Organize data which is collected from a controlled scientific investigation.
 - Data should be organized in charts which list the values for the independent variable in the first column and list the values for the dependent variable in a column to the right of the independent variable.

Example Charts:

| Independent Variable | Dependent Variable |
|----------------------|--------------------|
| | |

(Or)

| Independent Variable | | | | Dependent Variable |
|----------------------|---------|---------|---------|--------------------|
| | Trial 1 | Trial 2 | Trial 3 | |
| First value | | | | |
| Second value | | | | |
| Third value | | | | |
| (other values) | | | | |

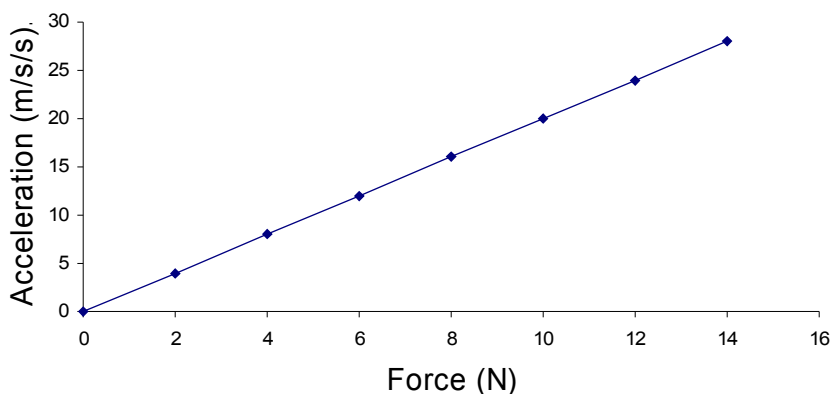
- Use graphs to organize data from controlled investigations.
 - Data should be recorded on a graph with the independent variable plotted on the “X” axis and the dependent variable plotted on the “Y” axis.
 - Choose scales for both the horizontal axis and the vertical axis.
 - There should be two data points more than is needed on the vertical axis.
 - The horizontal axis should be long enough for all of the data points to fit.
 - The intervals on each axis should be marked in equal increments.

Scientific Inquiry

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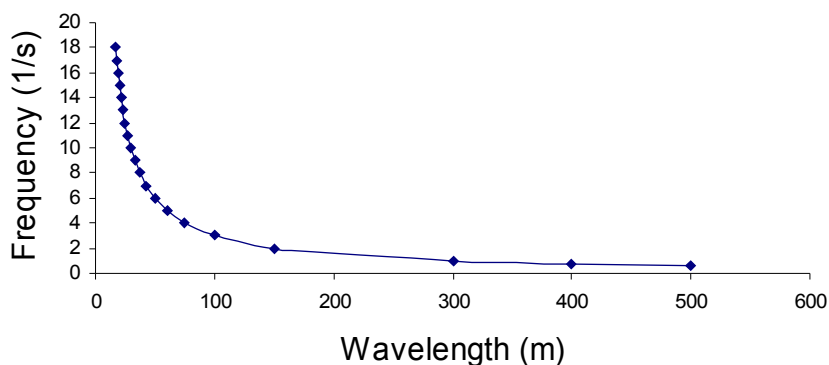
- Label each axis with the name of the variable and the unit of measure.
- Title the graph.
- Use the graphs to analyze and interpret data to determine a relationship between the dependent and independent variables.
 - A line graph is used for continuous quantitative data.
 - A bar graph is used for non-continuous data which is usually categorical.
 - A circle graph shows a relationship among parts of a whole. Circle graphs often involve percentage data.
- Recognize the implications of various graphs
 - A *direct variation* (or proportion) is one in which, one variable increases as the other increases or as one variable decreases the other decreases. A straight line with a positive slope indicates a direct relationship that changes at a constant rate. A greater slope indicates an increased rate of change.

Force vs Acceleration



- An *inverse variation* (or proportion) is one in which the product of two quantities is a constant. For example the product of the frequency and the wavelength is equal to the velocity of a wave ($v = f\lambda$). Frequency and wavelength are inversely proportional. As one quantity increases the other quantity decreases.

Wavelength vs. Frequency



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Use a *formula* to solve for one variable if given the value for the other variables.

- Use *dimensional analysis* to change the units of the measurement determined, not the value of the measurement itself.
 - It is very important in science to express all numbers with units of measurement when appropriate, not just the number as is sometimes done in purely mathematical problems.
 - To change a measurement from liters to milliliters, or grams to kilograms, for example, the measurement can be multiplied by a “conversion factor” that expresses the relationship between the given and asked- for value.
 - This conversion factor is a fraction equal to one and, therefore, the *value* of the original measurement does not change---only the *unit* changes.

$$15 \text{ liters} \times \frac{1000 \text{ milliliters}}{1 \text{ liter}} = 15,000 \text{ milliliters}$$

(conversion factor)

$$15 \text{ milliliters} \times \frac{1 \text{ liter}}{1000 \text{ milliliters}} = 0.015 \text{ liters}$$

- Understand that a *scientific model* is an idealized description of how phenomena occur and how data or events are related. A scientific model is simply an idea that allows us to create explanations of how we think some part of the world works. *Models* are used to represent a concept or system so that the concept may be more easily understood and predictions can be made.
 - The model of the atom helps us understand the composition, structure, and behavior of atoms. Models for the atom can change as new information and theories explain the atom more completely.
 - No model is ever a perfect representation of the actual concept or system. Models may change over time as scientific knowledge advances.
- Understand that *technology* (tools/machines or processes) can be used to develop better understanding of the science concepts studied. As technology improves, science concepts are studied more completely and more accurately.
- Understand how to organize and analyze data using technology such as graphing calculators or computers.

It is not essential that students memorize formulas for relationships between dependent and independent variables studied.

Assessment Guidelines:

The first objective of this indicator is to organize data from a controlled scientific investigation; therefore the primary focus of assessment should be to use formulas, graphs, charts, tables or models to organize the data into a structure that illustrates the relationship between the variables.

Another objective of this indicator is to interpret data from a controlled scientific investigation, therefore the primary focus of assessment should be to change one form of data representation into another meaningful representation.

In addition to *organize* and *interpret*, assessments may require that students:

- Illustrate the relationship between two variables in a scientific investigation;
- Interpret variable relationships using formulas, graphs, models, or technology;
- Use the procedure of dimensional analysis to change the units of measurement of data.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.6 Evaluate the results of a controlled scientific investigation in terms of whether they refute or verify the hypothesis.

Taxonomy Level: 5.1-B Evaluate Conceptual Knowledge

Key Concepts:

controlled scientific investigation

hypothesis

Previous/Future knowledge: Students planned and conducted controlled scientific investigations beginning in the 5th grade (5-1.3). They evaluated results to formulate valid conclusions beginning in the 5th grade (5-1.6), and they generated questions to formulate a hypothesis (5-1.1). In Physical Science, students are introduced to testing a hypothesis by designing a controlled scientific investigation (PS-1.4) and organizing and interpreting data by using mathematics, graphs, models, and technology (PS-1.5). In chemistry (C-1.6) students will expand their knowledge of scientific investigation by including what the possible sources of error might be. In physics (P-1.9) students will communicate and defend a scientific argument or conclusion.

It is essential for students to-

- Understand that in a controlled scientific investigation the *hypothesis* is a prediction about the relationship between an independent and dependent variable with all other variables being held constant.
- Understand that results of a controlled investigation will either refute the hypothesis or verify by supporting the hypothesis.
 - After the hypothesis has been tested and data is gathered, the experimental data is reviewed using data tables, charts, or graphical analysis.
 - If the data is consistent with the prediction in the hypothesis, the hypothesis is supported.
 - If the data is not consistent with the prediction in the hypothesis, the hypothesis is refuted.
- Understand that the shape of a graph can show the relationship between the variables in the hypothesis. (See graph shapes in PS-1.5)
- Understand that if the data does support the relationship, the hypothesis is still always tentative and subject to further investigation. Scientists repeat investigations and do different investigations to test the same hypothesis because the hypothesis is always tentative, and another investigation could refute the relationship predicted.
- Understand that scientific laws express principles in science that have been tested and tested and always shown to support the same hypothesis. Even these laws, however, can be shown to need revision as new scientific evidence is found with improved technology, advanced scientific knowledge, and more controlled scientific investigations based on these.

It is not essential that students

- Develop new hypotheses if the results have refuted the tested hypothesis;
- Carry out statistical analysis on the collected data.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

Assessment Guidelines:

The objective of this indicator is to evaluate results of a controlled scientific investigation in terms of whether they refute or verify/support the hypothesis, therefore, the major focus of the assessment should be to critique the data (tables, charts, and graphical analysis) from an investigation to determine if the results support the relationship predicted between variables in the hypothesis.

In addition to *evaluate*, assessments may require that students:

- Infer that a hypothesis is verified or refuted by the results of the investigation;
- Compare data that supports or refutes a hypothesis;
- Explain why the results of an investigation support or refute a hypothesis;
- Analyze the data from an investigation to see if it supports or refutes the hypothesis.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.7 Evaluate a technological design or product on the basis of designated criteria (including cost, time, and materials).

Taxonomy Level: 5.1-B Evaluate Conceptual Knowledge

Key Concepts:

Technological design or product

Criteria: cost, time, materials

Previous/Future knowledge: In the 5th grade (5-1.7), students used a simple technological design process to develop a solution or product. In the 6th grade (6-1.4), students planned and produced a solution or product using a technological design process which included identifying a problem, designing a solution or product, implementing the design, and evaluating the solution or product. Technological design will continue to be developed at a higher level in biology, chemistry, and physics.

It is essential for student to

- Understand that technological designs or products are produced by the application of scientific knowledge to meet specific needs of humans. The field of engineering focuses on these processes.
- Understand that there are four stages of technological design:
 - Problem identification
 - Solution design (a process or a product)
 - Implementation
 - Evaluation
- Understand that common requirements within the solution design stage of all technological designs or products include:
 - Cost effectiveness or lowest cost for production;
 - Time effectiveness or the least amount of time required for production, and
 - Materials that meet specific criteria, such as:
 - Solves the problem
 - Reasonably priced
 - Availability
 - Durability
 - Not harmful to users or to the environment
 - Qualities matching requirements for product or solution
 - Manufacturing process matches characteristics of the material
- Understand that benefits need to exceed the risk.
- Understand that there are tradeoffs among the various criteria. For example, the best material for a specific purpose may be too expensive.

It is not essential for students to

- Recognize which field of engineering is involved with specific products or designs.
- Match specific materials that would be best for specific technological designs or products without being given characteristics of the given materials.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

Assessment Guidelines:

The objective of this indicator is to evaluate a technological design or product on the basis of designated criteria, therefore, the primary focus of the assessment should be to critique a technological design or product to determine if it meets designated criteria.

In addition to *evaluate*, assessments may require students to:

- Exemplify the best product based on given criteria;
- Analyze the best product or design from a given set based on associated criteria.
- Compare given products or designs on the basis of given criteria to select the best.
- Summarize the qualities of the best product or design based on given criteria.
- Infer from given criteria and qualities which product or design matches best.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.8 Compare the processes of scientific investigation and technological design.

Taxonomy Level: 2.6-B Understand Conceptual Knowledge

Key Concepts:

Science, Technology

Scientific investigation

Technological design

Previous/Future knowledge: In the 5th grade and 6th grades, students used technological design process (5-1.7) and (6-1.3), and from the 4th grade (4-1.3) on up, students have summarized characteristics of controlled scientific investigations. In Physical Science (PS-1.7), students evaluated technological designs or products. Building on this knowledge, students will compare processes of scientific investigations and technological designs. Scientific investigations and technological design will continue to be developed in biology.

It is essential for students to

- Understand that *science* is a process of inquiry that searches for relationships that explain and predict the physical, living and designed world.
- Understand that *technology* is the application of scientific discoveries to meet human needs and goals through the development of products and processes.
- Understand that the processes of *scientific investigation* are followed to determine the relationship between an independent and dependent variable described by a hypothesis. The results of scientific investigations can advance science knowledge.
- Understand that the processes of *technological design* are followed to design products or processes to meet specified needs. The results of technological designs can advance standard of living in societies.
- Understand that, in general, the field of engineering is responsible for technological designs or products by applying science to make products or design processes that meet specific needs of mankind.
- The process of controlled scientific investigations:
 - Asks questions about the natural world;
 - Forms hypotheses to suggest a relationship between dependent and independent variables;
 - Investigates the relationships between the dependent and independent variables;
 - Analyzes the data from investigations and draws conclusions as to whether or not the hypothesis was supported.
- The technological design process is used to design products and processes that people can use. The process may involve:
 - A problem or need is identified
 - A solution is designed to meet the need or solve the problem identified.
 - The solution or product is developed and tested.
 - The results of the implementation are analyzed to determine how well the solution or product successfully solved the problem or met the need.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

Some ways that the two processes might be compared:

| Scientific Investigation | Technological Design |
|--|---|
| Identifies a problem – asks a question | Identifies a problem or need |
| Researches related information | Researches related information |
| Designs an investigation or experiment | Designs a process or a product |
| Conducts the investigation or experiment – repeated trials | Implements the design or the process – repeated testing |
| Analyzes the results | Analyzes the results |
| Evaluates the conclusion – did the results refute or verify the hypothesis | Evaluates the process or product – did it meet the criteria |
| Communicates the findings | Communicates the product or process |

It is not essential that students

- Distinguish which field of engineering is associated with specific technological designs.

Assessment Guidelines:

The objective of this indicator is to *compare* the processes of scientific investigation and technological design; therefore, the major focus of assessment should be to detect the similarities and differences in the processes of controlled scientific investigation and technological design.

In addition to *compare*, students should be able to:

- *Exemplify* the processes of scientific investigation and technological design;
- *Classify* a process as either part of a scientific investigation or technological design given a description of the steps;
- *Summarize* steps that may be part of each process;
- *Illustrate* the processes of scientific investigation and/or technological design in words, diagrams or pictures;
- *Recognize* each process based on whether it advances scientific knowledge or designs products or processes that meet specific needs of mankind.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.9 Use appropriate safety procedures when conducting investigations.

Taxonomy Level: 3.2-C Apply Procedural Knowledge

Key Concepts:

Safety procedures

Investigations

Previous/Future knowledge: Since kindergarten, students have been expected to use appropriate safety procedures when conducting investigations. In Physical Science, students are expected to use specific safety procedures associated with the investigations in this course.

It is essential for students to

- Practice the safety procedures stated in every scientific investigation and technological design problem conducted in the laboratory and classroom. Follow safety procedures regarding
 - Personal safety – follow only the designated lab procedures; be sure to understand the meaning of any safety symbols shown, wear proper clothing and shoes for the lab, use protective equipment (goggles, aprons,...), tie back loose hair, never eat or drink in lab room, use proper technique for touching or smelling materials.
 - Work area safety – use only designated chemicals or equipment, keep work area clear and uncluttered, do not point heated containers at yourself or anyone else, be sure all burners or hot plates are turned off when the lab is finished, know the location and use of the fire extinguisher, safety blanket, eyewash station, safety shower, and first aid kit, disconnect electrical devices, follow clean-up procedures as designated by the teacher.
- Safely and accurately practice appropriate techniques associated with the equipment and materials used in the activities conducted in the laboratory and classroom (see PS-1.2 for materials lists).
- Abide by the safety rules in the course safety contract.
- Report any laboratory safety incidents (spills, accidents, or injuries) to the teacher.

NOTE TO TEACHERS – safety while working with students:

- Textbooks have lists of “Safety Procedures” appropriate for the suggested activities. Students should be able to describe and practice all of the safety procedures associated with the activities they conduct.
- Teachers should weigh the “risks vs. the benefits” of doing any scientific investigation with students.
- Teachers should emphasize the investigation procedures, as well as the safety procedures before doing an activity.
- Lab safety rules should be posted in the classroom and laboratory where students can view them. Students should be expected to learn these rules and pass a test on them showing mastery. Students should understand the importance of these rules and conduct investigations by following them. Putting themselves or others in danger by not following a safety rule is not tolerated.

NOTE TO TEACHERS – teacher responsibility regarding safety:

- Follow safety and facility guidelines as outlined in the
 - SC Lab Safety CD – CD and training available from the SC Department of Education,
 - Lab Safety flipchart, and
 - SC School Facilities Guide.

Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

- Science laboratories should be equipped with the proper safety equipment.
- Students should be carefully instructed about laboratory safety rules and assessed to determine mastery of the appropriate techniques before doing any laboratory activities. (Textbooks have safety guidelines and safety notes are included with the laboratory activities.)
- Laboratory safety contracts should be signed by the students and their parents or guardians and kept on file to protect the teacher, school, and school district.
- Laboratory safety violations and accidents should be reported in writing with witness signatures to administrators, duplicated, dated, and kept on file.
- Materials Safety Data Sheets (MSDS) should be kept on file and accessible to all teachers for all chemicals in the laboratory areas. (Several science companies provide CDs with all their MSDS on them for distribution to all science teachers in the school.)
- Each school district and/or school should have a Chemical Hygiene Plan according to OSHA guidelines.

Assessment Guidelines

The objective of this indicator is to use appropriate safety procedures, therefore, the primary focus of the assessment should be for students to practice appropriate safety procedures. In this case, students must have an understanding of which safety procedures should be used with given investigations. Assessments may require that students understand which procedures are not appropriate for conducting investigations safely.

In addition to *use*, assessments may require that students:

- Recognize appropriate safety procedures for conducting investigations.
- Exemplify appropriate safety procedures for conducting investigations.
- Classify a procedure as an appropriate or not appropriate safety procedure associated with an investigation.
- Illustrate appropriate safety procedures for conducting investigations.